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Declarations under Rule 4.17:
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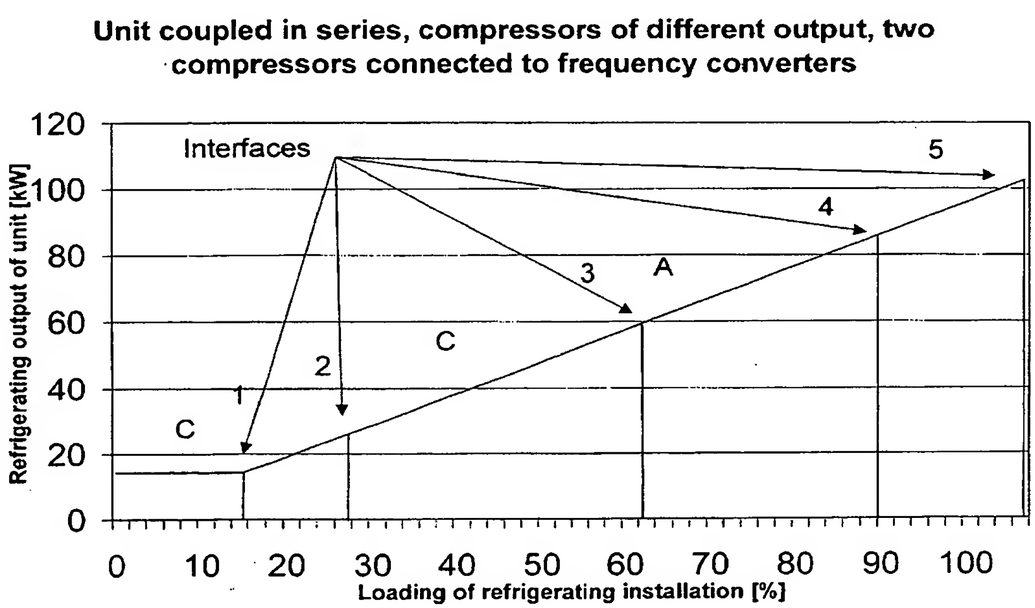
[Continued on next page]

(54) Title: METHOD FOR CONTROLLING REFRIGERATING INSTALLATION



(57) Abstract: The invention relates to a method for controlling refrigerating installations, the method comprising steps of selecting two or more compressors, at least two of which differ in output, connecting one or more of the selected compressors each to its own frequency converter, coupling the selected compressors in series so as to provide a refrigerating unit, controlling the frequency range of the compressors controlled by the frequency converters such that they provide continuous power control and controlling the obtained refrigerating unit to meet the required output need by starting and stopping the compressors and by controlling the frequency of the compressors connected to the frequency converters.

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CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, UZ, VC, VN, YU, ZA, ZM, ZW, ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG)

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METHOD FOR CONTROLLING REFRIGERATING INSTALLATION

BACKGROUND OF THE INVENTION

[0001] The invention relates to a method for controlling refrigerating installations in accordance with the preamble of claim 1, in which method two or more compressors are coupled in series and their output is controlled to meet the need in each particular case.

[0002] It takes large and powerful refrigeration installations to refrigerate large spaces. Currently, these spaces are refrigerated by units coupled in series, which usually comprise 3 to 6 compressors coupled in series from their cold side. Conventionally power control of these installations takes place independently of the control system as so-called on-off control of the compressors, whereby compressors are switched on or off one by one according to the required output power. Consequently, the power control always takes place stepwise. For instance, when employing a unit with four compressors coupled in series, the power control steps are 0-25-50-75-100%, the smallest step being 25%. This means that for achieving 26% output, the control system must start a second compressor, in addition to one compressor, and consequently the output produced with these two compressors is 50%. As a result of excessive output production, the control system stops the second compressor in a moment, and is compelled to restart it later on. Thus, in order to control the required output and maintain a desired temperature it is necessary to start and stop the compressors tens of times a day.

[0003] The above-described arrangement has a drawback that each start-up stresses the compressor, which shortens the service life of the compressors and the electric devices.

[0004] The invention thus relates to a method for controlling a refrigerating unit, which method provides stepless power control and eliminates unnecessary starting and stopping of compressors.

BRIEF DESCRIPTION OF THE INVENTION

[0005] It is an object of the invention to provide a method by which the above problem can be solved. It is achieved with a method, which is characterized by what is disclosed in the characterizing part of claim 1. The preferred embodiments of the invention are disclosed in the dependent claims.

[0006] The invention is based on adding to the control system of the unit at least one frequency converter, which is able to operate in a predeter-

mined frequency range. The frequency converter is connected to a specific compressor, or if there are several frequency converters, they are each connected to a separate compressor. In addition, the compressors are selected such that at least some of them differ from one another in size. In this manner it is possible to provide stepless power control and to avoid unnecessary starting operations of the compressors, whereby the power that the unit takes from the mains is always in relation to the power required for maintaining a desired temperature. To achieve the stepless power control the compressors employed should be selected such that of the two or more selected compressors at least two differ in output. Thus, utilizing the frequency converter it is possible to achieve continuous power control that is stepless within each power range.

[0007] An advantage with the method and system according to the invention is that unnecessary starting and stopping of the compressors can be avoided, which in turn increases the service life of the compressors and the electric devices. At the same time, energy consumption of the refrigerating unit is reduced, because at each loading level of the refrigerating installation the input power of the unit corresponds to the power required for maintaining the desired temperature.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] In the following the invention will be described in greater detail in connection with preferred embodiments, with reference to the attached drawings, in which

Figure 1 is a schematic view of in-series coupling of a conventional refrigerating unit comprising three equal compressors, in which all compressors are controlled by on-off control;

Figure 2 illustrates the relation of the refrigerating output/input of the refrigerating unit to the loading of the refrigerating installation;

Figure 3 is a schematic view of in-series coupling of a conventional refrigerating unit comprising three equal compressors, in which one compressor is controlled by a frequency converter and two compressors by on-off control;

Figure 4 illustrates the relation of the refrigerating output/input of the refrigerating unit of Figure 3 to the loading of the refrigerating installation;

Figure 5 is a schematic view of in-series coupling of a refrigerating unit comprising three equal compressors, in which two compressors with lower

output are controlled by a frequency converter and one compressor with higher output is controlled by on-off control;

Figure 6 illustrates the relation of the refrigerating output/input of the refrigerating unit of Figure 5 to the loading of the refrigerating installation.

DETAILED DESCRIPTION OF THE INVENTION

[0009] In the following, control of a refrigerating unit is examined first by means of prior art and then the description proceeds to the solution of the present invention.

[0010] Figure 1 shows in-series coupling of three identical compressors of type A, in which all the compressors are controlled by on-off control. The power control steps of the unit are thus 0 – 33.3 – 66.7 – 100% and consequently the lowest power step is 33.3%. In this solution, power control is only performed by starting and stopping the compressors in accordance with the output required at any particular time, which means that the power control is always performed stepwise. Figure 2 shows the relation of the input/output power of the unit of Figure 1 to the loading of the refrigerating installation. The solution corresponding to Figure 2 employs three identical standard semi-hermetic piston compressors, with product name Bitzer 4N-20.2Y, and the refrigerant is R-404A, suction gas temperature is +25 °C, liquid supercooling 0 K and design conditions –10 °C vaporization temperature (usage for temperatures above zero) and +40 °C liquefaction/condensation temperature.

[0011] In the case of Figures 1 and 2, as the loading level is more than 0%, the first compressor starts up controlled by suction pressure/temperature, the refrigerating output being 31.95 kW. In practice, this means that the refrigerating output of the unit remains constant (31.95 kW) until the loading of the refrigerating installation rises to exceed 33.3%, whereby a second compressor starts up as the loading increases, and two compressors being in operation the refrigerating output of the unit is 63.9 kW. As the loading increases further to exceed 66.6% a third compressor starts, whereby the unit achieves its maximum refrigerating output 95.85 kW. It appears from Figure 2 that the loading situation and refrigerating output of the unit do not correspond. This means that the refrigerating output of the unit does not adapt to the loading of the refrigerating installation at a particular time, and consequently, to maintain the desired temperature in the cooled compartment requires that the compressors be started and stopped on a continuous basis so as to adapt the

temperature of the cooled compartment to the loading of the refrigerating installation.

[0012] By increasing the number of compressors the control accuracy of the unit of the above-described type improves, because the steps will be smaller and the number thereof will be higher. But, the price and space requirement of the installation increase in proportion. In addition, it is difficult to design the installations such that they meet the need accurately.

[0013] In accordance with Figure 3, more modern and advanced applications employ three identical compressors coupled in series, one of which, the B-type compressor, is controlled by means of a frequency converter. Conventionally, the extended power frequency range of compressors of this type is 25 to 70 Hz, the power frequency of a standard A-type compressor with on-off control being constant 50 Hz. Figure 4 illustrates the relation of the refrigerating output/input of this application to the loading of the refrigerating installation. The solution corresponding to Figure 4 employs three identical standard semi-hermetic piston compressors with product name Bitzer 4N-20.2Y and the refrigerant is R-404A, suction gas temperature is +25 °C, liquid supercooling 0 K and design conditions being –10 °C vaporization temperature (usage for temperatures above zero) and +40 °C liquefaction/condensation temperature.

[0014] In these applications, as the loading increases to exceed 0%, a compressor controlled by a frequency converter starts at the minimum frequency 25.12 Hz controlled by suction pressure or temperature. The compressor controlled by the frequency converter operates at said minimum frequency up to the loading level of 17%. If the loading increases further, the frequency of the frequency-converter-controlled compressor increases as well up to 69.34 Hz, whereby the loading of the refrigerating installation is about 43%. In this manner it is possible to achieve continuous power control within the loading range of about 17 to 43%. If the loading continues to grow to exceed 43%, the first compressor with on-off control starts at the standard frequency of 50 Hz and the frequency of the compressor controlled by the frequency converter decreases to 25.95 Hz. Within the loading range of about 43 to 51%, the refrigerating output of the unit remains constant, and thus, the frequency of the compressor controlled by the frequency converter remains at 25.95 Hz. As the loading increases from 51% upwards, the frequency of the compressor controlled by the frequency converter increases in accordance with the loading to

the value 68.51 Hz, whereby the loading of the refrigerating installation is about 76%. As the loading grows further to exceed about 76%, the second compressor with on-off control also starts at the standard frequency 50 Hz and the frequency of the compressor controlled by the frequency converter decreases to 25.54 Hz. All three compressors are then in use. Within the loading range of about 76 to 84% the refrigerating output of the unit remains constant and hence the frequency of the compressor controlled by the frequency converter also remains at 25.54 Hz. As the loading grows from 84% upwards, the frequency of the compressor controlled by the frequency converter also grows in accordance with the loading to the value of 70.17 Hz, the two compressors with on-off control operating at the frequency of 50 Hz. The maximum refrigerating output of the unit is then achieved, which in this exemplary embodiment is 105.44 kW, which corresponds to about 110% loading of the refrigerating installation.

[0015] It should be noted that in the application as described above, between the power ranges there are power control dead points, in which the control is not fully continuous. In these power ranges the compressors start and stop unnecessarily as described in the first example. In addition it should be noted that by using one compressor controlled by a frequency converter is possible to achieve an extended power control range, about 17 to 110%, which is considerably larger than the power control range of an application without a frequency converter.

[0016] The previous examples describe prior art, but in the method according to the present invention the compressors to be used are selected in a novel manner and at the same time frequency converters are utilized such that dead points in the power control included in the previous example can be avoided and the control of the unit will be completely stepless.

[0017] The present invention is characterized in that all of the compressors to be installed in the unit are not identical and that at least one of the compressors is controlled by means of a frequency converter. In addition, the compressors are to be controlled such that they start in a given, predetermined order and that the frequency ranges of the compressors controlled by the frequency converter are sufficient to provide continuous power control. Hence, it should be taken into account that the compressors starting first, or first and second, in a loading situation, must always be the ones controlled by the fre-

quency converters, in order that powers at the lower end of loading could be controlled steplessly.

[0018] For instance, if we examine the above prior art unit comprising one compressor controlled by the frequency converter its power control could be rendered continuous by selecting two compressors with on-off control such that their output is lower. Thus, the dead points of Figure 4 would become nonexistent. For instance, when only a compressor controlled by a frequency converter is in use at the lower end of loading, its frequency rises to the maximum as the loading increases. As the frequency is at the maximum, the output of the compressor is also at the maximum, and when the first compressor with on-off control is started and the frequency of the compressor controlled by the frequency converter decreases to the minimum, the unit achieves output which is roughly the same as the output achieved by the frequency converter alone at the maximum frequency. The procedure is the same for selecting a second compressor with on-off control. In this manner it is possible to provide continuous power control in the whole loading range.

[0019] It should be noted that loading values which make one more compressor to start or stop, depending on changes in loading, can be modified by altering the power frequency range of the compressors controlled by the frequency converters. However, this has to be carried out such that the outputs/performances of the compressors selected for use will be taken into account, so that no dead points will occur in the power control.

[0020] Figure 5 shows schematically three compressors coupled in series according to one embodiment of the present invention. The unit of the invention is characterized in that at least two compressors are selected, at least one of which is controlled by means of a frequency converter, and that the compressors differ in output. The invention is characterized in that it is also possible to select all the compressors to be different in output. By providing the unit with compressors of different sizes and by using them in the unit in the below-described manner in different power ranges it is possible to avoid the dead points in power control appearing in the prior art solution.

[0021] The following will examine the embodiment set forth in Figure 5 of the present invention. In this embodiment, three compressors are selected, two of which are of type C and one of type A. The C-type compressors have lower output that the A-type compressor, and in addition, the C-type compressors are controlled by frequency converters, whereas the A-type com-

pressor employs on-off control. In the example of Figure 6, the A-type compressor is a standard semi-hermetic piston compressor, with product name Bitzer 4N-20-2Y and the C-type compressors are similar but one size smaller with product name Bitzer 4P-15.2Y and they operate in the frequency range of 25 to 70 Hz. The refrigerant used is R-404A, suction gas temperature is +25 °C, liquid supercooling 0 K and design conditions –10 °C vaporization temperature (usage for temperatures above zero) and +40 °C liquefaction/condensation temperature.

[0022] In the application of refrigerating installation according to Figures 5 and 6, as the loading level exceeds 0%, one of the compressors provided with a C-type frequency converter starts, controlled by suction pressure/temperature, at the minimum frequency, which in this exemplary embodiment is 25.85 Hz. The started compressor operates at the minimum frequency until the loading of the refrigerating installation rises to 15%, at which level there is load curve interface 1. As the loading of the refrigerating installation increases further to exceed 15%, the frequency of the operating compressor controlled by the frequency converter increases correspondingly to 49.19 Hz, the output of the compressor then corresponding to about 28% loading level, and at the same point a second interface 2 is reached. If the loading continues to grow to exceed 28%, also the other C-type compressor controlled by the frequency converter starts at the minimum frequency 25.12 Hz and the frequency of the operating compressor controlled by the frequency converter reduces to 25.12 Hz. In that case, there are two C-type compressors controlled by the frequency converter in active use, and both of them operate at the frequency of 25.12 Hz. As the loading increases further, the frequency of the compressors increases simultaneously or non-simultaneously, for instance, to the frequency of 55.11 Hz. Then is reached interface 3 of Figure 6, at which the loading of the refrigerating installation is about 62%.

[0023] When the loading of the refrigerating installation exceeds 62%, an A-type compressor with on-off control starts at the frequency of 50 Hz. At the same time, the operating frequency of the two C-type compressors controlled by the frequency converters reduces to 24.88 Hz. As the loading increases further, the frequency of the two C-type compressors controlled by the frequency converters rises to 49.82Hz, while the A-type compressor operates at the standard frequency of 50Hz, whereby are achieved interface 4 and the refrigerating output of about 86 kW, which corresponds to 90% loading of the

refrigerating installation. When the loading of the refrigerating installation exceeds 90%, it is possible to raise the frequency of the C-type compressors controlled by the frequency converters to 69.80 Hz, whereby the refrigerating output corresponding to 107% loading is achieved. When the loading reduces, the system works steplessly in the corresponding manner in the inverse order.

[0024] It appears from Figure 6 that this exemplary embodiment of the present invention provides an extended power control range, the minimum being 15% and the maximum 107%. As it is also noted, the compressor selection provides a situation, in which there are no dead points between the power ranges, but the power control is completely continuous and follows closely each particular loading level.

[0025] In the above-described example the frequency range of interface 1 is 25.85 Hz, whereby the loading/power control range of the refrigerating installation is about 15%. By setting interface 1 as low as possible, it is possible to control the refrigerating output of the unit at low loading levels more accurately than before. However, in selecting the interface frequency ranges it should be taken into account, as is done in the previous example, that no dead points are allowed on the output/load curve, at which continuous power control would be impossible. In addition, crossings of any one interface or some interfaces can be locked to a time span, suction pressure or temperature, in order to provide the installation with optimal operating area in terms of energy consumption.

[0026] The invention can thus be applied to units of all types, in which a plurality of compressors are coupled in series. The invention is not restricted to a given number of compressors but it can be applied to units of all sizes, provided that the compressor sizes are carefully selected. In addition, the unit may comprise a large number of compressors controlled by frequency converters. In the above-described preferred embodiments of the invention, the refrigerating installation is used for providing temperatures above zero, but the invention can just as well be used for providing temperatures below zero.

[0027] It is apparent to the person skilled in the art that as technology advances the basic idea of the invention can be implemented in a variety of ways. Thus, the invention and the embodiments thereof are not restricted to the above-described examples but they may vary within the scope of the claims.

CLAIMS

1. A method for controlling refrigerating installations, **characterized** in that the method comprises the steps of

selecting two or more compressors, at least two of which differ in output;

connecting one or more of the selected compressors each to its own frequency converter;

coupling all the selected compressors in series so as to form a refrigerating unit;

setting frequency ranges of the compressors controlled by the frequency converters to be sufficiently large so as to enable continuous power control;

controlling the operation of the obtained refrigerating unit to meet the required output need by starting and stopping the compressors, at least two of which differ in output, in a given predetermined order and by controlling the frequency of the compressors connected to the frequency converters.

2. A method as claimed in claim 1, **characterized** in that all the compressors are selected such that they differ in output.

3. A method as claimed in claim 1 or 2, **characterized** in that a frequency converter is connected to all the compressors.

4. A method as claimed in claims 1 to 3, **characterized** in that the compressor that starts first in a loading situation is controlled by means of a frequency converter.

5. A method as claimed in claim 4, **characterized** in that two compressors are selected, at least one of which is controlled by means of a frequency converter and that the compressors are selected such that they differ in output and the frequency range employed by the compressor controlled by the frequency converter is set sufficiently large so as to provide continuous power control of the refrigerating installation.

6. A method as claimed in claim 4, **characterized** in that three compressors are selected, at least one of which is controlled by means of a frequency converter and that at least two compressors are selected such that they differ in output and the frequency range employed by the compressor controlled by the frequency converter is set sufficiently large so as to provide continuous power control of the refrigerating installation.

7. A method as claimed in claim 4, **c h a r a c t e r i z e d** in that four compressors are selected, at least one of which is controlled by means of a frequency converter and that at least two compressors are selected such that they differ in output and the frequency range employed by the compressor controlled by the frequency converter is set sufficiently large so as to provide continuous power control of the refrigerating installation.

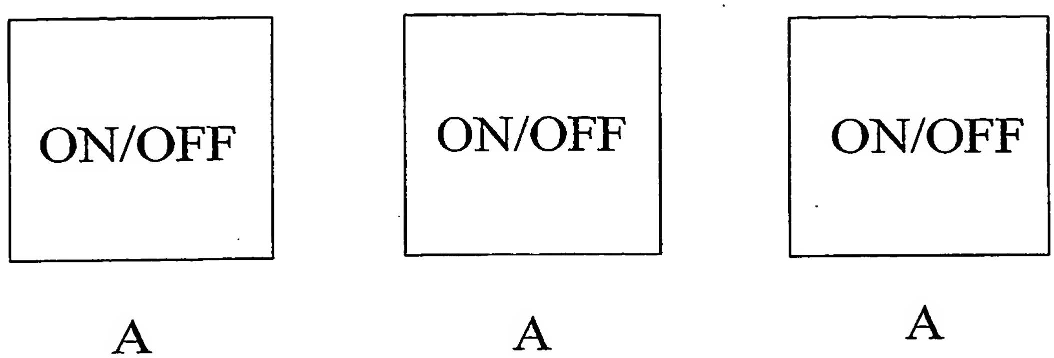

FIG. 1

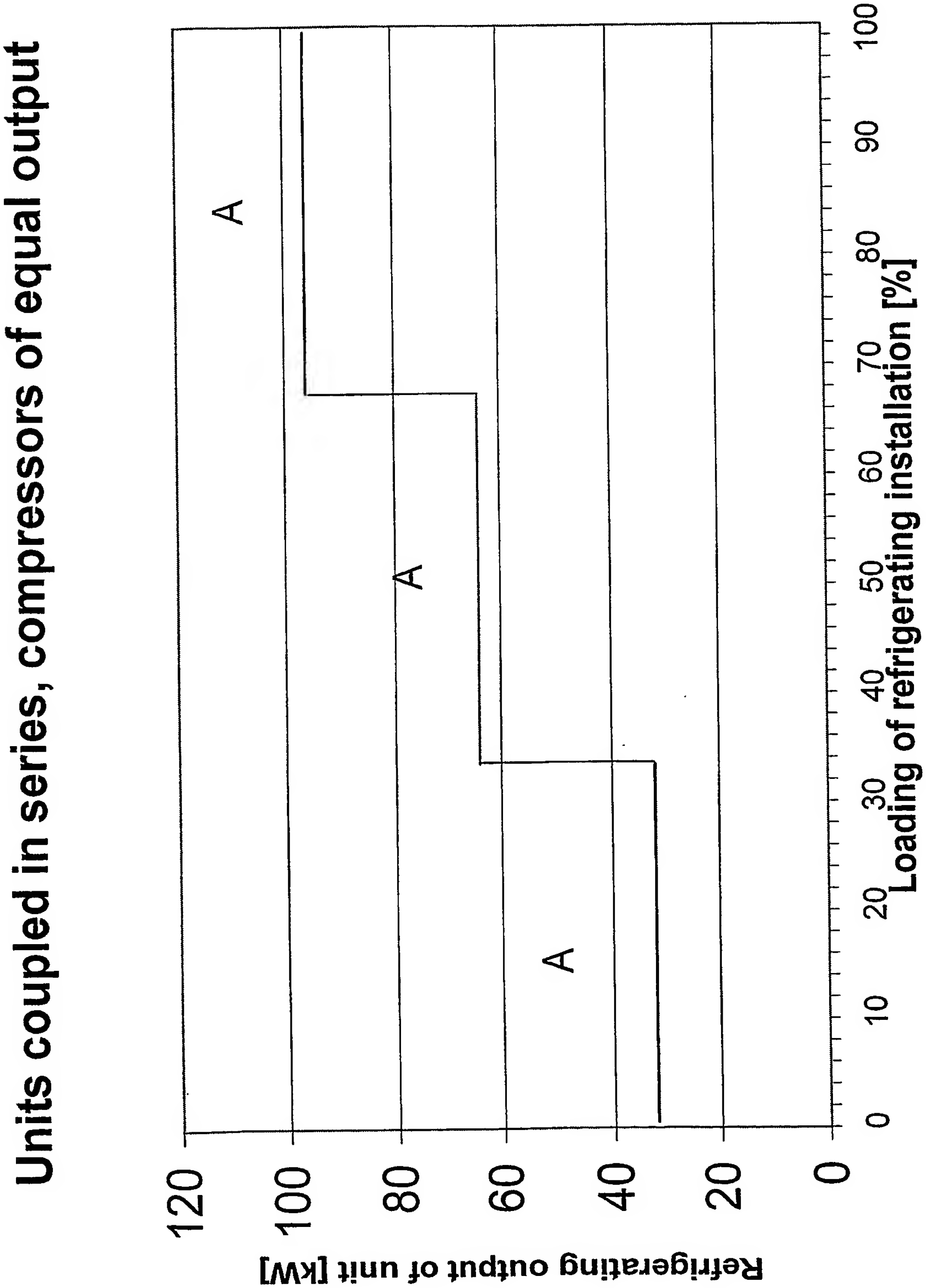
Units coupled in series, compressors of equal output
Refrigerating output of unit [kW]
0
20
40
60
80
100
120
Loading of refrigerating installation [%]
0
10
20
30
40
50
60
70
80
90
100
A
A
A

FIG. 2

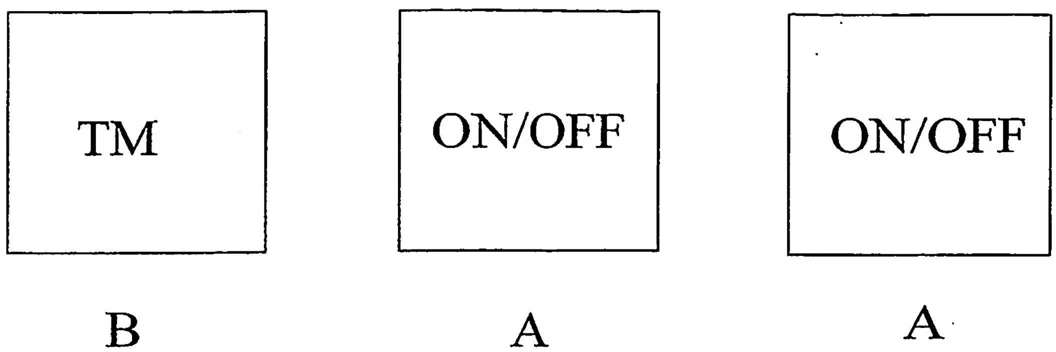

FIG. 3

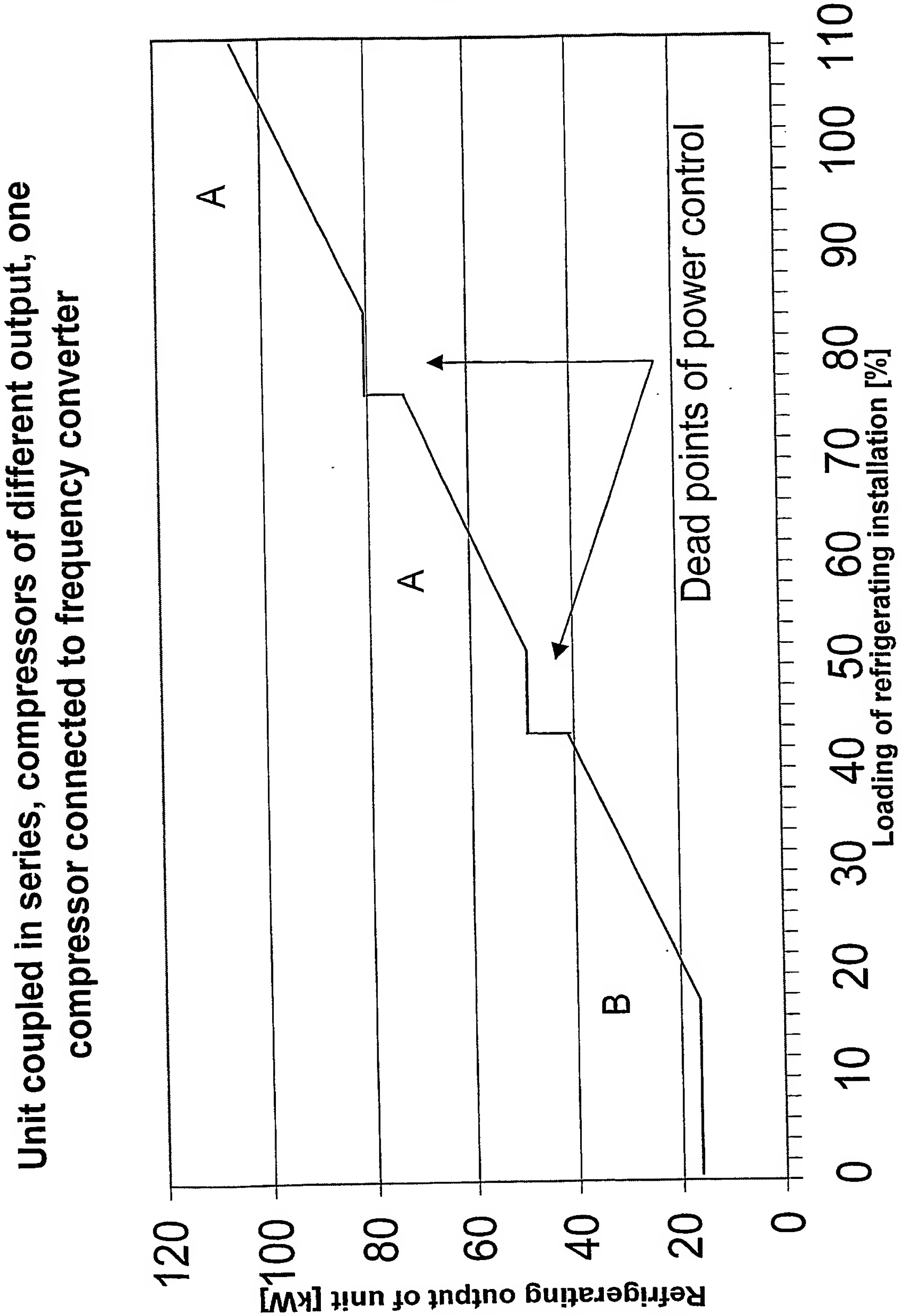
Unit coupled in series, compressors of different output, one compressor connected to frequency converter
A
A
B
Dead points of power control
Refrigerating output of unit [kW]
120
100
80
60
40
20
0
Loading of refrigerating installation [%]
0
10
20
30
40
50
60
70
80
90
100
110

FIG. 4

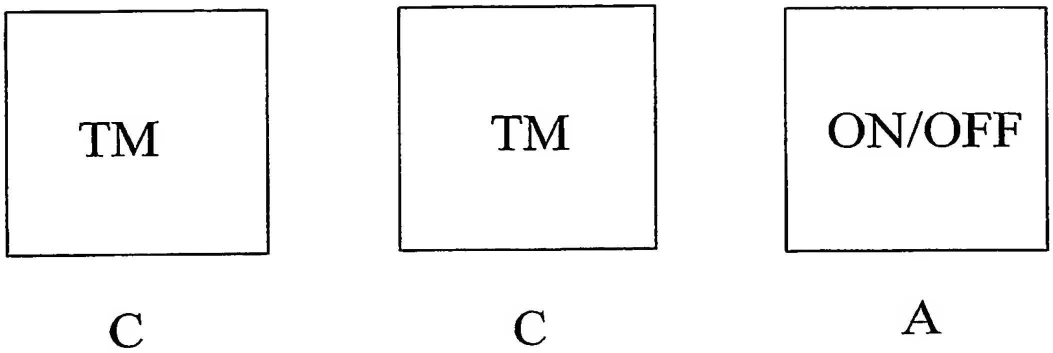

FIG. 5

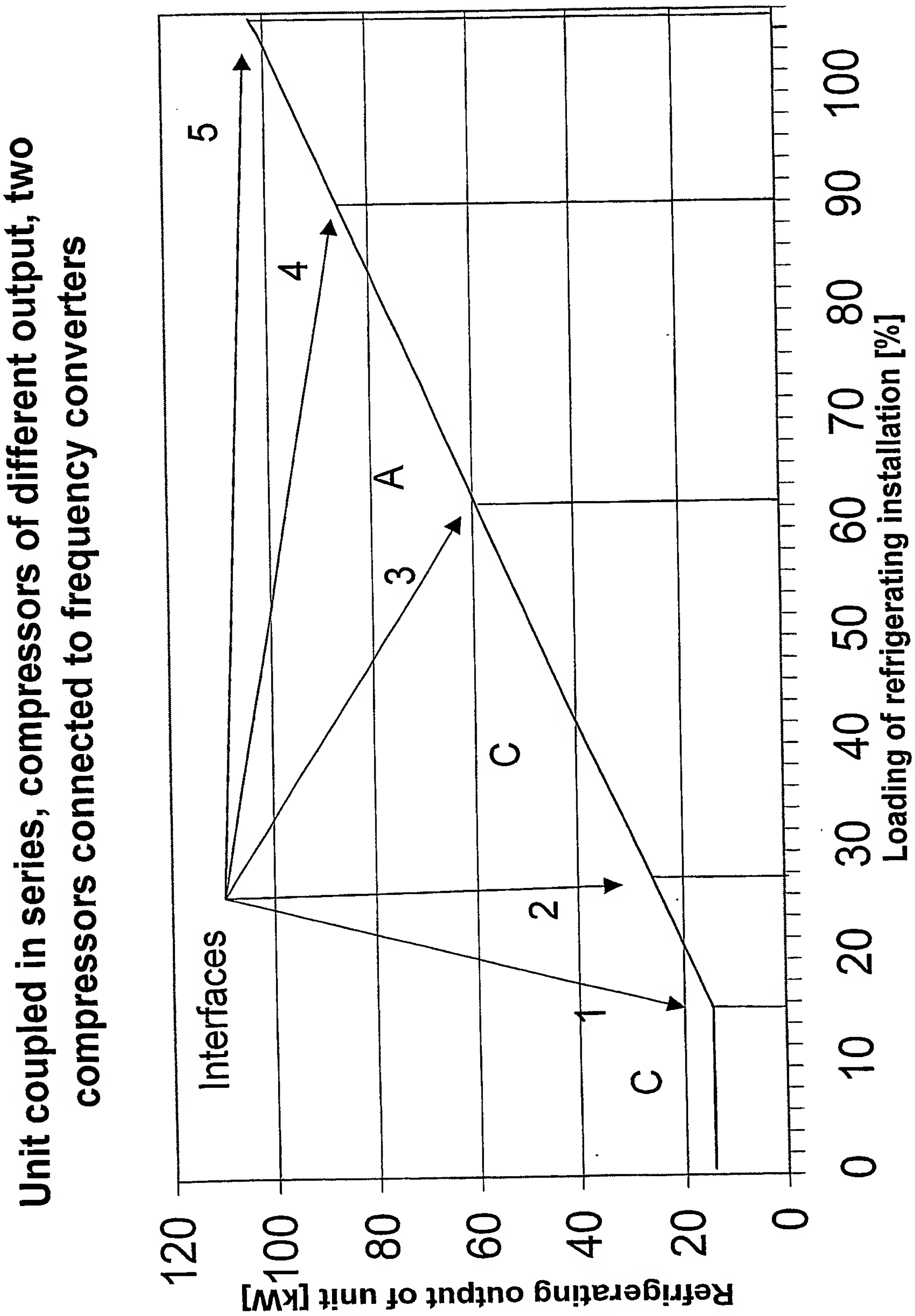
Unit coupled in series, compressors of different output, two compressors connected to frequency converters
Refrigerating output of unit [kW]
120
100
80
60
40
20
0
Loading of refrigerating installation [%]
0
10
20
30
40
50
60
70
80
90
100
Interfaces
1
2
3
4
5
A
C
C

FIG. 6

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: F25B 49/02, F25B 1/10
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: F25B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-INTERNAL, WPI DATA, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4787211 A (D.N. SHAW), 29 November 1988 (29.11.88), column 3, line 10 - column 7, line 17, figures 1-4 --	1
Y	WO 9851976 A1 (KYLMÄTERMO OY), 19 November 1998 (19.11.98), whole docuent --	1-7
Y	US 2453095 A (W.L. MCGRATH), 2 November 1948 (02.11.48), column 10, line 47 - column 11, figure 3 --	1-7
Y	US 4152902 A (L.E. LUSH), 8 May 1979 (08.05.79), column 1 - column 4, line 16 --	1-7

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents:

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

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"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
28 May 2003	30-05-2003
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Inger Löfving / MRo Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI 03/00134

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	FR 2807823 A1 (ENERGIE ET TRANSFERT THERMIQUE), 19 October 2001 (19.10.01), whole document -- --------	1-7

Patent document cited in search report			Publication date	Patent family member(s)			Publication date
US	4787211	A	29/11/88	CA	1296194	A	25/02/92
				DE	3716393	A	19/11/87
				ES	2003313	A	16/10/88
				FR	2598788	A,B	20/11/87
				GB	2192735	A,B	20/01/88
				GB	8711583	D	00/00/00
				IT	1204634	B	10/03/89
				IT	8720562	D	00/00/00
				JP	63025388	A	02/02/88
				US	4748820	A	07/06/88
				US	4594858	A	17/06/86
				US	4947655	A	14/08/90
WO	9851976	A1	19/11/98	AU	7434198	A	08/12/98
				FI	972020	A	14/11/98
US	2453095	A	02/11/48	NONE			
US	4152902	A	08/05/79	NONE			
FR	2807823	A1	19/10/01	NONE			

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